THE UNIVERSITY OF ALBERTA

ENCODING AT THE SENSORY REGISTERS

A BI - SENSORY STUDY

BY

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ABSTRACT

A bi-sensory experiment was conducted to investigate the characteristics of the stimulus representation which is transferred from the sensory registers to the short-term stores. In particular, the acoustic nature of the representation was considered within the model for sensory registers and short-term stores presented by Atkinson and Shiffrin (1968).

A film consisting of numerical aural-visual stimulus pairs was presented to thirty university students. Each stimulus presentation consisted of a visual digit and a disparate aural digit which appeared simultaneously for .125 seconds. Three such pairs, separated by .125-second intervals, constituted a presentation trial. Free recall and two directed recall orders were employed. Subjects responded randomly in either the written or spoken response modes. Sixty trials were administered, but only data from the final thirty were analyzed. Differences among presentation modes, recall orders, and recall modes were investigated.

Recall of aural stimuli was found to be significantly better than recall of visual stimuli. Significant differences were also found within the recall order dimension, free recall being superior to either directed recall order. Differences between written recall and spoken recall were not significant.

Limitations inherent within bi-sensory experimental frameworks minimized conclusions of an acoustic code between the sensory registers and the short-term store. The superiority of recall of aural stimuli was concluded to support phonetic reading instruction and audio-based machine teaching. Applications of the stimulus presentation method were considered within both memory and paired-associate learning research.

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A [illegible] array of numerical aural-visual stimulus input was presented to thirty university students. Each stimulus presentation consisted of a visual digit and a disparate aural digit which occurred simultaneously for .125 second. Three stimulus pairs, separated by .125 second intervals, constituted a presentation trial. Free recall and two directed recall orders were employed. Subjects responded randomly in either the written or speech response modes. Sixty trials were administered, but only data from the final thirty were analyzed. Interactions among presentation modes, recall orders, and recall modes were investigated.

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CHAPTER I

INTRODUCTION

During the past decade, as psychological researchers have become increasingly concerned with the quality of error as well as criterion responses, systematic errors have been reported with aurally presented material. Moser and Fotheringham (1960), using digits spoken against a white noise, found a high error rate (50%) and have produced a digit-confusion matrix which suggests perceptual confusions. Curry, Fay and Hutton (1960) have shown that, in good listening conditions, letters of the alphabet spoken at ordinary-speech sound levels do indeed yield apparent errors of perception.

Explanation of a psychological phenomena need not be restricted to a single framework, however. Conrad (1964) presented a decay theory interpretation using an experimental design which minimized perceptual confusion while maintaining systematic errors. This study, combined with others including Conrad (1962, 1965), Conrad and Hull (1964), and Wickelgren (1965a, 1965b); suggested that the observed errors were in fact the result of acoustic confusion, but with the error occurring within the short-term memory store rather than during perception. From these findings, Conrad and others have hypothesized the existence of acoustic encoding in the storage of verbal materials.

Descriptions of a system's characteristics, however, may not necessarily be the most efficient way of developing an understanding of its operations. Concurrent with the acoustic-confusion research, theoreticians were occupied with memory-model construction. Among the many

designs proposed, several--including those of Atkinson and Shiffrin (1968), Bower (1967), Broadbent (1957), and Waugh and Norman (1965)--share a common concern: the unitary, sequential processing of information input by some central facility in short-term memory.

The present study is concerned with the further illumination of the acoustic encoding phenomena and its interpretation within contemporary memory models.

Existence of an aural encoding process in immediate memory would seem of considerable educational importance. If, for example, such an aural code exists, phoneme-based reading instruction would be deemed superior to "sight reading" methods. Such a finding would also provide theoretical support for audio-visual aids in classroom instruction. Indeed, even the long-perplexing problem of teaching reading skills to the hearing-handicapped might become more theoretically enlightened.

Discovery of processes within immediate memory also is of more than passing educational importance. Sperling (1960) has illustrated the large amount of information that the mind is capable of perceiving almost simultaneously and Smith (as reported by Miller, 1956) has shown how trained coding strategies can effectively increase the information storage capacity of short-term memory. Perhaps by discovering the characteristics of encoding processes, efficient, trainable strategies may be developed which will increase the usable processing capacity of the immediate memory system.

CHAPTER II

REVIEW OF RELATED LITERATURE

Ebbinghaus (1885), in the first experimental study of memory, was interested in the re-appearance in consciousness of seemingly long lost mental states. He defined memory to include the processes of learning, retention, association, and reproduction. Moreover, he delineated three categories of stored experiences: those that are reproduced voluntarily in consciousness, those that are reproduced involuntarily in consciousness, and those which do not return *in toto* to consciousness, but nonetheless affect conscious processes. Ebbinghaus' subsequent study attempted to elucidate the variables which influence the categorical storage of mental states.

Though Ebbinghaus did not present a memory model, his distinction of consciousness and stored mental states is the precursor of the modern two-component memory model. James (1890) dichotomized memory into primary and secondary memory stores. He defined these terms introspectively: an event in primary memory has never left consciousness and is part of the psychological present, while an event recalled from secondary memory has been absent from consciousness and belongs to the psychological past. Waugh and Norman (1965) have modernized James' presentation and have used it as the basis for their theoretical exploration.

Although opposed by some psychologists as being contrary to the concept of parsimony (Melton, 1963), a two-component memory model has become the modern basis for interpreting memory processes. Miller's (1956) magical number seven, plus or minus two, is based on a two-part

memory. The theories of Broadbent (1957), Norman (1968), and others are similarly founded. Indeed, much recent memory research has been conducted within the two-component framework.

Adams (1967), supporting the division of memory into two components, short-term (STM) and long-term (LTM) stores, presented three main lines of evidence: the capacity of STM is less than the capacity of LTM; LTM and STM respond to different kinds of interference; and physiological observations based on the loss of transfer of material from STM to LTM following surgical bilateral lesion of the medial-temporal lobe.

Using arguments similar to Adams' first two, contemporary memory researchers support the further segmentation of memory into three components: sensory register, short-term store, and long-term store (Atkinson and Shiffrin, 1968; Bower, 1967). Sperling's (1960) illustration of the rapid loss of some perceived information and his subsequent work delineating the iconic store, combine with the temporal factors of acoustic and semantic interference in support of the differentiation of STM into a sensory register and a short-term store.

On the basis of these studies, Atkinson and Shiffrin (1968) promulgate a memory system structurally divided into the three components diagrammed in Figure 1: the sensory register, the short-term store, and the long-term store.

The first component, the sensory register, provides an immediate registration of a stimulus within the appropriate sensory dimension. A representation of the stimulus registration is next transferred to the second component, the short-term store, which constitutes a subject's

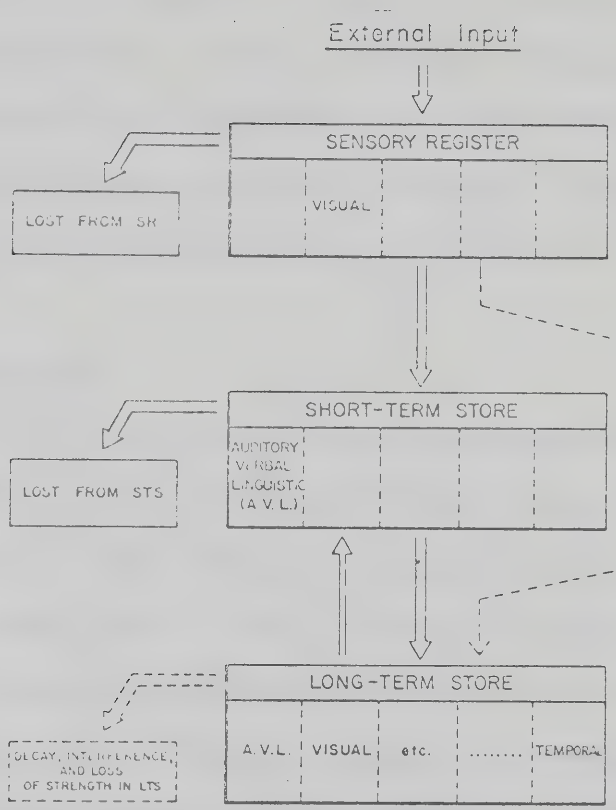

Figure 1: Structure of the Memory System [1]

"working memory". It is within this store that most elaborative and conceptual functions occur. The third component, the long-term store, is a relatively permanent recepticle of information transferred to it from the short-term store and the sensory register. Each component is characterized according to structural and control dimensions. The permanent features of memory, that is the structural features, include both the physical systems and the unvarying processes. Control processes, conversly, are selected, constructed, and used at the option of the subject. Structural features, then, are those aspects of memory, such

as memory components, decay characteristics and information capacities, which are fixed from situation to situation. Coding procedures, search strategies, and rehearsal systems--in general, those operations which may be manipulated by the subject to suit situational variants--are among the many aspects of memory which may vary among situations and are, therefore, classed as control processes.

The Sensory Register

An initial visual registration system with a rapid rate of image decay and an output to a common auditory-verbal-linguistic (a.v.l.) short-term store has been investigated by such workers as Sperling (1960, 1963), Averbach and Coriell (1961), and Estes and Taylor (1964, 1966). Using tachistoscopically presented letter and number arrays, the existence, within this registry, of a highly accurate visual image which decays in several hundred milliseconds has been inferred. Since the sensory register apparently lacks rehearsal capacities, not all stimulations are necessarily transferred to higher-order memory systems. Scanning and selection of transferred material appears to be made at the discretion of the subject (Sperling, 1960).

Few research projects have investigated registers in sensory modalities other than the visual. Atkinson and Shiffrin postulate comparable systems though they caution that the widely differing structures of the different senses cast doubt on the existence of similar registration systems.

The Short-term Store

Atkinson and Shiffrin restrict their concept of a short-term store to include only the auditory, verbal and linguistic memory processes. They suggest that comparable systems may exist for other short-term memories, but do not elaborate. Essentially, the STS is characterized by initial acoustic confusion (Conrad, 1964), subsequent semantic confusion (Baddeley, 1964), limited capacity (Miller, 1956), subject-controlled rehearsal processes (Atkinson and Shiffrin, 1965), and stimulation decay in approximately thirty seconds. The stimulus representation in STS is considerably more elaborate than in the sensory register, suggesting an information retrieval from LTS based on the initial registration (see Figure 1) and a multi-component stimulus trace (Bower, 1967). Any information in STS is transferred to some degree to LTS (Hebb,1961; Melton, 1963), but the amount and form of the information transferred may be influenced by the subject.

The Long-term Store

The long-term store includes the processes of permanent storage of material copied from STS and the search for,and retrieval of, previously deposited information. As they did with the STS, Atkinson and Shiffrin restrict the concept of LTS to material being transferred from or to the a.v.l. store. They acknowledge the existence of long-term memories in each of the other sense modalities.

Information may be stored in LTS as either a multicomponent trace (Bower, 1967), or a multi-copy trace (Atkinson and Shiffrin, 1965). In either case, the information may be searched for, and retrieved according to, any one of many dimensions. Storage and retrieval are

both control processes. Though trace decay is minimal, interference effects may disrupt or impair retrieval functions.

Acoustic Confusion

Conrad (1962, 1964), comparing the confusion matrices constructed from a recall task of visually presented letters and a listening task of letters spoken over white noise, found significant similarities among errors within the two tasks. He concluded that "the majority of subjects verbalized the stimuli rather than attempting to store them in visual form."[2] Subsequent research by Baddeley (1966), Conrad (1965), Conrad, Freeman and Hull (1965), Conrad and Hull (1964), and Wickelgren (1965a, 1965b, 1966) is confirmatory of the existence of acoustic interference. The phenomenon has been illustrated using letters, words, and numbers; and using both the visual and the aural presentation modes. Conrad, Sperling, and Wickelgren hence postulated that visual stimuli are coded acoustically for representation in short-term memory.

Although presentation mode is apparently not a factor in acoustic confusion, presentation rate is a factor in acoustic confusion. Laughery and Pinkus (1966) found acoustic confusion occurring at presentation rates of three items per second. As presentation rate decreases from one item per second, acoustic confusions decrease and are inconsistently observed at the two-seconds-per-item rate (Adams, Thorsheim and McIntyre; 1969a, 1969b). Conrad (1967) and Adams _et al_ (1969b) also found that acoustic interference effects decrease rapidly as retention intervals increase. Adams _et al_ (1969b) and Laughery and Pinkus also found that the duration of the item presentation influenced the phenomenon.

The temporal nature of acoustic confusion effects suggests, then, that the phenomena occurs during the initial operations on the stimulus representation. Atkinson's and Shiffrin's (1968) hypothsis that the locale of confusion is the transfer of the representation from the sensory register to the a.v.l. store appears tenable.

Bi-sensory Stimulation

Experiments using simultaneous stimulation of two sense organs (either from the same or differing sense modalities) generally have been performed and interpreted within the mechanical model for memory and attention proposed by Broadbent (1957, 1958). Unfortunately, though Broadbent's original theory stipulates a single processing unit common to all senses, his and others' subsequent concern with channel switching and filter theory has precluded discussion of the nature of the stimulation which is transferred from the sense receptors to the processing unit. Rather than become restricted by the limitations of Broadbent's model (Margrain, 1967; Moray, 1960), one may analyze bi-sensory results within other frameworks.

Simultaneous presentation studies also have tended to utilize presentation rates too slow to isolate sensory register processes. Broadbent and Gregory (1961, 1965) presented but one digit per second; Murdock (1965) used two words per second; Yntema and Trask (1963) presented words and digits at two per second; Madsen, Rollins and Senf (1970) used several rates, the fastest of which was two pairs per second. Indeed, only Moray (1960) used a rate (four pairs per second) which approached the decay time of the visual sensory register. Sperling

(1960) found that five visually presented items could be transferred from the sensory register to the short-term memory during the 250milli-seconds before trace decay occurred. Understandably, then, little substantial evidence concerning sensory registers or sensory-dependent (or independent) short-term memories appears to have been discovered by studies utilizing presentation times five-to-ten fold longer than that required for reception and coding in short-term memory.

In apparent contrast to Broadbent's switching theory, Sperling (1960) showed that, unless given specific stimulus selection instructions, subjects report a random selection of the briefly, but simultaneously, presented visual items. It is not unreasonable to expect, then, random sampling by STS of sensory registers unless subjects are instructed to the contrary (Atkinson and Shiffrin, 1968).

Bi-sensory studies have yielded, nonetheless, several interesting results. Margrain (1967) presented digit pairs simultaneously to both eye and ear and found an over-all superior retention of aurally presented material. She, thus, hypothesized the existence of separate visual and auditory short-term stores. Her results, though not inconsistent with her interpretation, also support a single a.v.l. store with a limited capacity "buffer-rehearsal system" (Atkinson and Shiffrin 1965). Items within the buffer are lost either through decay due to initially weak trace characteristics, or through removal from a full buffer when a new item is added. Margrain's lists of twelve numbers exceed most estimates of short-term memory capacity and, indeed, the total per trial recall of aural and visual digits was within the realm of Miller's (1956) seven, plus or minus two. Moreover, Sperling (1963)

predicted that visual information will decay more quickly than will auditory information. He suggested that the visual material may be translated into auditory information, resulting in equally stable memory.

Madsen et al (1970), also using simultaneous eye-ear presentations, found superior recall with aurally presented material. They proposed that the distinctive nature of the inputs provided retrieval tags of varying effectiveness. The relative success of short-term retention is inferred to be dependent upon the efficiency of stimulation encoding processes. Their data also supported storage strategies which are controlled by the subject. The Madsen et al study, though designed in part to test Broadbent's theory, seems amenable to re-interpretation within the Atkinson and Shiffrin model.

Footnotes

[1]Atkinson, R.C., and Shiffrin, R.M. Human Memory: a proposed system and its control processes. In K. W. Spence and J. T. Spence (eds.) The Psychology of Learning and Motivation. Vol. 2. New York: Academic Press, 1968, p 93.

[2]Conrad, R. Acoustic confusions in immediate memory. British Journal of Psychology, 1964, 53, p 79.

Hypotheses

In accordance with the Atkinson-Shiffrin three-component memory model, the following hypotheses are offered. It will be recalled that the Atkinson-Shiffrin model entails the acoustic representaion of visual material before storage in STS.

I. Presentation mode will affect retention and recall. If stimuli are presented bi-sensorially and simultaneously, the stimulation which is in a form more readily encoded will be more rapidly/readily stored in STS.

   A. Retention will be superior for the more rapidly/readily encoded stimulation; it will suffer less from decay and interference.

   B. Recall will be superior for the more repidly/readily encoded stimulation

   C. Recall order will favour the more rapidly/readily encoded stimulation.

II. Recall mode will not affect retention or accuracy of recall.

   A. Stimulations recovered from a common a.v.l. store will be subject to similar decoding processes for recall in a given mode.

   B. The effects of these decoding processes will be similar for all stimulations.

CHAPTER III

DESIGN AND PROCEDURE

Using Atkinson and Shiffrin's (1967) basic model for sensory registers and short-term stores, an experiment was designed to examine the nature of the stimulus representation transferred from the sensory registers to the short-term store. A competitive bi-sensory stimulation technique was employed.

Subjects were presented with simultaneous, disparate pairs of digits by an audio-visual method. Immediate recall was employed and the results were analyzed to determine the effects of presentation mode, recall order, and recall mode on the subject's receptions and retentions of the presented material.

Subjects

The experimental group consisted of thirty volunteer subjects with a minimum of one year university education. Mean age of the group was 22.0 years (mode: 23 years; range: 18 to 28 years). All subjects were studying courses offered by the Faculty of Education, University of Alberta, and had a mean post-secondary educational level of 3.27 years (mode: 4 years; range: 1 year to 6 years). Although efforts were made to balance the group according to sex, the final experimental group consisted of 13 females and 17 males. Several additional subjects participated, but their results were discarded because of equipment malfunctions. Each subject was observed under all experimental conditions.

Apparatus and Stimulus Materials

Aural and visual digits were presented simultaneously by a movie film sound projector with an earphone audio output. The stimuli were prepared on a 16 mm black-and-white movie film (with sound strip) which was projected at 24-frames per second. Instructions were presented via audio magnetic tape through the earphone output.

The stimulus film was presented in a small,darkened room, illuminated only by a low-intensity spot lamp concentrated on the subject's response pad. Black visual digits approximately 14 inches high were projected on an 18-inch by 30-inch white field. Subject-to-screen distance was approximately 6 feet. The Bell and Howell Filmosound 16 mm projector employed used a standard 300-watt quartz iodine projection lamp and an f1.4 lens. Aural items were presented through monaural earphones connected to the projector's audio amplification system. Considerable amplifier sounds provided a high level of white noise; accordingly, audio intensity was adjusted to common listening levels for each subject. As well as presenting aural stimuli, the earphones masked environmental noises.

Each visual stimuli was projected for .125 seconds (3 frames), while the corresponding aural stimulus occupied a .125-second segment of the film's sound track. The aural stimuli were initially prepared on magnetic audio tape, manually spliced to the appropriate duration, and subsequently optically printed on the film's sound track (see Appendix A).

The audio-visual stimuli were grouped into trials with three audio-visual pairs per trial. Within each trial, pairs were separated by .125 seconds of blank film. Immediately following the last stimulus

pair of each trial was a 1-second strip of coloured film base which functioned as a recall-order instruction. As the colour was projected, the experimenter presented a single-word recall mode command via a microphone audio override and the earphones. Recall instructions were followed by a 9-second strip of dark-purple film base which functioned as a response trial. The film's sound track was blank except for stimulus presentations. Preceeding each trial by two seconds, the film base changed from deep-purple to black, constituting a visual attention cue. Included in the film were 60 such trials which had a total projection time of 12 minutes.

Each recall instruction consisted of two components--an aural cue and a visual cue. The aural component prescribed one of two recall modes (spoken or written) while the visual component specified one of three recall orders (visual-then-aural, aural-then-visual, or free recall). Hence, there were six possible recall instruction combinations. The film's 60 presentaion trials were split in half, the first half used for task familiarization and the second half used for response measurements. Within each half of the film, each recall instruction combination was used on five rendomly-ordered trials.

Method

Subjects were presented individually with the stimulus film. The experiment was performed in a small, darkened room illuminated by a low-intensity spot lamp focused on the subject's response pad.

Following fitting with headphones, the subject listened to an instruction tape (see Appendix B) which briefly explained the task, established the recall order code, and discussed the recall mode command.

A typed copy of the instructions was also made available to the subject. The subject was then familiarized with the written response pad. Film projection was initiated and, on the first two trials, sound intensity was adjusted to an audible level. During the entire experimental session, the experimenter could communicate with the subject via the microphone audio override. As the coloured instruction strip ending each trial appeared, the experimenter presented the corresponding aural instruction via the microphone-earphone combination. The subject's spoken responses were recorded by the experimenter on an answer form (see Appendix C) while written responses were recorded on an answer pad divided into five rows and two columns. The experimenter subsequently transferred written responses to the master answer sheet. The subject's first correct spoken response was reinforced with an oral "good" from the experimenter. No further feedback was given.

At the conclusion of the film, the subject was given a printed de-briefing sheet and asked to complete a short questionaire.

CHAPTER IV

RESULTS

Experimental Design

The experiment constituted a three-dimensional factorial design with all factors repeated. Although somewhat unorthodox, this design was chosen to allow for balancing of instruction and attention effects across trials. In particular, recall order was repeated on subjects to minimize effects of selective attention; recall mode was repeated for similar reasons. In establishing the experimental design, the prime concern of the study--the illumination of the stimulus representation transferred from the sensory registers to the short-term store--determined proceedures. The initial dimension of the design, presentation mode, was the primary study variable; the remaining dimensions, recall order and recall mode, were included only to minimize external effects on the primary variable. Since interactions among dimensions were at once not expected and, more important, not pertinent to the considered lemma, the chosen repeated measures design was not a serious limitation.

Data were collected, combined into a three-dimensional framework, then analyzed on each dimension using a one-way analysis of variance for repeated measures procedure (see Figure 2).

		RECALL ORDER					
		visual-aural		aural-visual		free	
	STIMULUS MODE	aural	visual	aural	visual	aural	visual
RECALL MODE	oral						
	written						

Figure 2: Experimental Design

<u>Scoring</u>

Responses were scored according to three systems. Although sharing a common philosophical basis, the systems varied in their degree of liberalness and the extent to which perception, coding, and other extraneous errors could confuse measurements of encoding efficiency. Only the final thirty recall trials were scored for each subject.

Scoring System I

Responses to aural and visual items were scored separately and for each trial. Possible scores were 0 and 1; to achieve a 1 score, all three digits in the trial had to be recalled correctly and in the correct order.

Scoring System II

Responses were again scored separately for presentation mode and trial. Rather than the all-right, all-wrong approach of System I, partially correct responses were considered within this framework. Scores of 0,1,2, and 3 could be obtained, 1 point being awarded for each correctly recalled digit, recalled in its correct position.

Scoring System III

Responses were again scored separately for presentation mode and trial. In this the most liberal of the methods, partially correct responses were scored free of order criteria. Scores of 0,1,2 and 3 were possible on each mode of each trial, 1 point being awarded for each correctly recalled digit, irrespective of recall position.

Table 1: Examples of Scoring Systems

Presentation	Responses	Score I	Score II	Score III
482	482	1	3	3
482	284	0	1	3
482	248	0	0	3
482	162	0	0	1

Scoring Rationale

Using the Atkinson-Shiffrin memory model (1968), a correct response may be considered to involve three levels of operation: registration (perception); encoding in STS; and decoding from STS. In this instance, a completely correct response would entail successful application of each operation along at least four dimensions: digit A, digit B, digit C, and the order relationship among digits A, B, and C (when the required response on trial k is A B C). Thus, for a completely correct response, at least 12 operations must be performed successfully.

Only one of the three levels (4 of the 12 operations) is directly concerned with the encoding phenomena. Hence, errors other than encoding errors may occur and result in incorrect responses. From the response alone it is difficult to discern at which level the error occurred.

For example, 11 of the 12 operations could be successfully completed. The order, let us say, was incorrectly decoded, so that instead of A B C, the subject responded B A C. Within Scoring System I, the response would be scored 0. And yet, it cannot be concluded with certainty that the error is one of encoding and, hence, pertinent to the study, or if the error is one of registration or decoding and, hence, presently a confounding factor.

The more liberalized Scoring Systems II and III were therefore designed. Founded in the assumption that an item may be correctly stored on all dimensions, but incorrectly retrieved on one or more dimensions, the systems allow partially correct responses. Moreover, although correctly stored information may be retrieved incorrectly, incorrectly stored information will be retrieved correctly only at a chance level. Hence, although increasing the discriminating power of the scoring and minimizing the effects of confounding errors, the risk of becomming too liberal is only minimally enhanced.

From another view, there are 125 possible ways that the recognition-encoding-decoding function can be performed (5^3 ways: 3 levels of 5 alternatives per level). Of these possible ways, the majority are functions of erroneous operations at the registration or decoding levels. Within System I, an error at any level is attributed to encoding and results in a score of 0. Of the 125 ways, only 1 qualifies as a correct response. Whether or not the error occurs at the encoding level is indistinguishable.

Using the partial scoring of System II, 27 of the 125 posibilities may result in a score. If all the digits are correctly encoded, but only 1 is correctly decoded, the subject still scores. The confusion

of registration-encoding-decoding errors is reduced. The order criteria may be missed at any of the three levels, however, and still detract from the score.

Within Scoring System III, 64 of the possible 125 ways will result in a score. Very few possibilities exist that encoding steps may be completed correctly without achieving at least a partial score. In general, System III is the most liberal of the three methods. A score may be realized despite considerable interference at either the registration or decoding levels. Scores within this system are only minimally affected by confounding errors.

Upon completion of scoring, data were totalled for each of the 12 experimental conditions. The totals were further combined to yield subject scores on each level of each of the three dimensions.

Analyses

A one-way analysis of variance for repeated measures was performed on the data for each of the three experimental conditions. Method of analysis was the same for all scoring systems. That is, 9 one-way analyses were performed, one on each dimension on each scoring system.

Presentation Mode I

This analysis compared the number of correctly recalled visual trials with the number of correctly recalled aural trials. Results of the analysis are summarized in Table 3. Mean number of correctly recalled visual trials per subject was 13.72, while the number of correctly recalled aural trials per subject was 24.40. Thirty trials were presented in each mode. The superiority of aural recall is highly significant.

Table 3: Analysis of Presentation Mode at Scoring System I

Number of Subjects	30	Number of conditions		2
Condition means	visual 13.72		aural	24.40
Source of variation	SS	df	MS	$F_{obs.}$
between people	1281.73	29	44.20	
within people	2510.0	30	83.67	
treatments	1706.67	1	1706.67	61.61
residual	803.34	29	27.70	
total	6301.74	59		

Probability of F = 0.00000 df = 1/(n-1)

H_0: $\mu_1 = \mu_2$ H_1: $\mu_1 \neq \mu_2$

$\therefore$ H_o is rejected.

Recall Order I:

Recall orders (that is, the order--visual first then aural, aural first then visual, or free recall--in which subjects were instructed to respond) were compared in this analysis. Findings are summarized in Table 4. Of the 20 trials per order, subjects averaged 12.17 correct visual-aural responses, 12.33 correct aural-visual responses, and 13.70 correct free responses. The difference among the three orders was found to be highly significant beyond the p = .01 level.

Table 4: Analysis of Recall Order at Scoring System I

Number of subjects	30	Number of conditions		3
Condition means V-A	12.17	A-V 12.33		Free 13.70
Source of variation	SS	df	MS	$F_{obs.}$
between people	838.26	29	28.90	
within people	175.34	60	2.92	
treatments	42.46	2	21.23	9.2682
residual	132.87	58	2.29	
total	1013.60	89		

Conservative probability of F = 0.00492 df = 1/(n-1)

H_0: $\mu_1 = \mu_2 = \mu_3$ H_1: one of $\mu_1, \mu_2 \neq \mu_3$

$\therefore$ H_0 is rejected.

A Newman-Keuls analysis among means (Winer 1962, p114) was performed on the data. The results are summarized in Table 5. Differences between aural-visual recall and free recall, and between visual-aural recall and free recall were significant beyond the p = .01 level.

Recall Mode I

The mode in which recall was made, that is, whether recall was spoken or written, was compared in this analysis. Of the 30 possible correct responses per recall mode, subjects achieved means of 19.07 correct responses in the spoken mode and 19.10 correct responses in the written mode. No significant difference was found between the spoken and visual modes. Results are summarized in Table 6.

Table 5: Newman-Keuls of Recall Order at Scoring System I.

Condition	V-A	A-V	Free
Totals	12.167(30)	12.333(30)	13.700(30)
V-A	--	5	46
A-V		--	41
Free			--
$q_{\alpha=.01}$ (r,24)	3.96	4.55	
$q/\overline{nMS_{res}}$	32.83	37.72	

A. $H_0: \mu_1 = \mu_2$ $H_0: \mu_1 \neq \mu_2$

$\therefore$ H_0 fails to be rejected.

B. $H_0: \mu_1 = \mu_3$ $H_1: \mu_1 \neq \mu_3$

$\therefore$ H_0 is rejected.

C. $H_0: \mu_2 = \mu_3$ H_1 $\mu_2 \neq \mu_3$

$\therefore$ H_0 is rejected.

Table 6: Analysis of Recall Mode at Scoring System I.

Number of subjects 30 Number of conditions 2

Condition means spoken 19.07 written 19.10

Source of variation	SS	df	MS	$F_{obs.}$
between people	1276.08	29	44.00	
within people	96.50	30	3.22	
treatments	.02	1	.02	.0047
residual	96.48	29	3.33	
total	1372.58	59		

Table 6 (continued)

Probability of F = .94585 df = 1/(n-1)

H_o: $\mu_1 = \mu_2$ H_1: $\mu_1 \neq \mu_2$

$\therefore$ H_o fails to be rejected.

Presentation Mode II

Partial responses with digit and position criteria were compared for the visual and aural presentation modes. Of the possible maximum score of 90 on each mode, subjects averaged 56.30 on visually presented stimuli and 81.23 on aurally presented stimuli. The difference was found to be very highly significant. Results are summarized in Table 7.

Table 7: Analysis of Presentation Mode at Scoring System II.

Number of subjects	30		Number of conditions	2
Condition means	visual	56.30	aural	81.23
Source of variation	SS	df	MS	$F_{obs.}$
between people	6691.81	29	230.75	
within people	13573	30	452.5	
treatments	9325.1	1	9325.1	63.63
residual	4249.88	29	146.55	
total	20266.8	59		

Probability of F = 0.00000 df = 1/(n-1)

H_o: $\mu_1 = \mu_2$ H_1: $\mu_1 \neq \mu_2$

$\therefore$ H_o is rejected.

Recall Order II

The number of correct partial responses meeting position and digit criteria were considered on the recall order dimension. Maximum possible score was 60 per recall order. Condition means were 44.77 for the V-A order, 45.30 for the A-V order, and 47.93 for the free recall. The differences were significant beyond the $p = .01$ level. Table 8 contains a summary of the findings.

Table 8: Analysis of Recall Order at Scoring System II

Number of subjects	30		Number of conditions		3	
Condition means	V-A	44.77	A-V	45.30	Free	47.93
Source of variation	SS		df	MS	$F_{obs.}$	
between people	4360.62		29	150.37		
within people	779.38		60	12.99		
treatments	172.44		2	86.22	8.239	
residual	606.94		58	10.46		
total	5140		89			

Conservative probability of F = 0.00758 df = 1/(n-1)

H_0: $\mu_1 = \mu_2 = \mu_3$ H_1: one of $\mu_1, \mu_2 \neq \mu_3$

$\therefore H_0$ is rejected.

Condition means were also analyzed within a Newman-Keuls framework. The difference between V-A recall and free recall was significant at $p = .01$. The difference between A-V recall and free recall was also significant at $p = .01$. Findings are summarized in Table 9.

Table 9: Newman-Keuls of Recall Order at Scoring System II.

Conditions		V-A	A-V	Free
	Totals	44.767(30)	45.3(30)	47.933(30)
V-A		--	19	95
A-V			--	79
Free				--
$q_{\alpha=.01}$ (r,24)		3.96	4.55	
$q\sqrt{nMS_{res}}$		70.17	80.63	

A. $H_0: \mu_1 = \mu_2$ $\quad H_1: \mu_1 \neq \mu_2$

$\therefore H_0$ fails to be rejected.

B. $H_0: \mu_1 = \mu_3$ $\quad H_1: \mu_1 \neq \mu_3$

$\therefore H_0$ is rejected.

C. $H_0: \mu_2 = \mu_3$ $\quad H_1: \mu_2 \neq \mu_3$

$\therefore H_0$ is rejected.

Recall Mode II

Differences between spoken and written recall were calculated using scores derived from partial responses meeting digital and positional criteria. Mean number of partially correct responses per subject was 68.87 for spoken recall and 68.67 for written recall. Maximum possible score was 90 in each instance. No significant difference was found between the recall modes. Table 10 summarizes the findings.

Table 10: Analysis of Recall Mode at Scoring System II.

Number of subjects 30 Number of conditions 2

Condition means spoken 68.87 written 68.67

Source of variance	SS	df	MS	$F_{obs.}$
between people	6691.81	29	230.75	
within people	753	30	25.10	
treatments	.625	1	.625	.0241
residual	752.38	29	25.94	
total	7444.81	59		

Probability of F = .87774 df = 1/(n-1)

$H_0: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$

$\therefore H_0$ is rejected.

Presentation Mode III

Visual and oral presentation modes were compared using scores derived from partially correct responses meeting only digital criteria. Means of 71.30 for the visual stimuli and 82.10 for the aural stimuli were observed. Maximum possible score was 90. The difference was very highly significant. Analysis results are presented in Table 11.

Table 11: Analysis of Presentation Mode at Scoring System III.

Number of subjects	30		Number of conditions	2
Condition means	visual	71.30	aural	82.10
Source of variation	SS	df	MS	$F_{obs.}$
between people	3056.69	29	105.40	
within people	4198	30	139.93	
treatments	1749.69	1	1749.69	20.7249
residual	2447.31	29	84.42	
total	7254.69	59		

Probability of F = 0.00009   df = 1/(n-1)

H_0: $\mu_1 = \mu_2$ H_1: $\mu_1 \neq \mu_2$

$\therefore$ H_0 is rejected.

Recall Order III

V-A recall, A-V recall, and free recall were compared using scores compiled from partially correct responses meeting digital criteria. Of maximum possible scores of 60 per recall order, means of 49.50 for the V-A condition, and 50.03 for the A-V condition, and 53.07 for free recall were observed. The differences were found to be significant beyond the p = .01 level. Results are presented in Table 12.

A Newman-Keuls analysis among means was also performed on the data. Results of this analysis are summarized in Table 13. The difference between V-A recall and free recall was significant at p = .01 level. The difference between A-V recall and free recall was significant at the p = .01 level also.

Table 12: Analysis of Recall Order at Scoring System III.

Number of subjects	30		Number of conditions	3	
Condition means	V-A 49.50		A-V 50.03	Free 53.07	
Source of variation	SS	df	MS	$F_{obs.}$	
between people	2309.12	29	79.62		
within people	1155.38	60	19.26		
treatments	222.12	2	111.06	6.902	
residual	933.25	58	16.09		
total	3464.5	89			

Conservative probability of F = 0.00205 df = 1/(n-1)

H_0: $\mu_1 = \mu_2 = \mu_3$ H_1: one of $\mu_1, \mu_2 \neq \mu_3$

$\therefore$ H_0 is rejected.

Table 13: Newman-Keuls of Recall Order at Scoring System III.

Condition		V-A	A-V	Free
	Totals	49.5(30)	50.03(30)	53.07(30)
V-A		--	16	107
A-V			--	91
Free				--
$q_{\alpha=.01}$ (r,24)			3.96	4.55
$q/\overline{nMS_{res}}$			87.0	99.96

A. H_0: $\mu_1 = \mu_2$ H_1: $\mu_1 \neq \mu_2$ $\therefore$ H_0 fails to be rejected.

B. H_0: $\mu_1 = \mu_3$ H_1: $\mu_1 \neq \mu_3$ $\therefore$ H_0 is rejected.

C. H_0: $\mu_2 = \mu_3$ H_1: $\mu_2 \neq \mu_3$ $\therefore$ H_0 is rejected.

Recall Mode III

Partial responses meeting digital criteria were analyzed along the recall mode dimension. A mean of 77.80 was observed under the spoken condition while a mean of 75.57 was observed under the written recall condition. The difference was significant beyond the p = .05 level. Results are presented in Table 14.

Table 14: Analysis of Recall Mode at Scoring System III.

Number of subjects	30		Number of conditions	2
Condition means	spoken	77.80	written	75.57
Source of variation	SS	df	MS	$F_{obs.}$
between people	3047.5	29	105.09	
within people	469.5	30	15.65	
treatments	73.81	1	73.81	5.4969
residual	394.69	29	13.61	
total	3517	59		

Probability of F = 0.02611 df = 1/(n-1)

$H_0: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$

$\therefore H_0$ is rejected.

In addition to the analysis discussed above, several graphs were also prepared. Figure 3 presents condition means for each dimension at Scoring System I. Figure 4 presents the comparable plots for Scoring system II, while Figure 5 presents the condition means for Scoring System III. Figure 6 is a plot of F_{obs} for presentation mode at each

scoring level, while Figure 7 and Figure 8 present similar information for recall order and recall mode.

Analysis of Free Recall Data

An additional analysis was performed on order data derived from free recall trials. Experimental data suggested a change in free recall strategy by many subjects as the experiment progressed: many subjects initially responded in an aural-visual order, but shifted to a visual-aural order on latter trials. To discern if such a change in strategy did occur, the number of V-A responses occurring on free recall trials in the first half of the experiment was compared with the number of similar responses in the second half. A corresponding analysis was performed for A-V responses.

Although the number of trials considered was the same for each half of the experiment, subjects responded to fewer trials on the initial half than on the latter half. An increase in V-A responses resulted in an increase in total responses on the second half on the test. Analyses of variance found a significant difference ($p=.05$) between V-A responses on the first and second halves; the difference between test halves for the A-V order was not significant. Data are summarized in Table 15.

Table 15: Order Data on Free Recall Trials

		ORDER				
		V-A		A-V		Total
		number responses	per cent responses	number responses	per cent responses	
PORTION OF TEST	1	86	33.7%	169	66.3%	255
	2	110	41 %	158	59 %	268
	Total	196	37.5%	327	62.5%	523

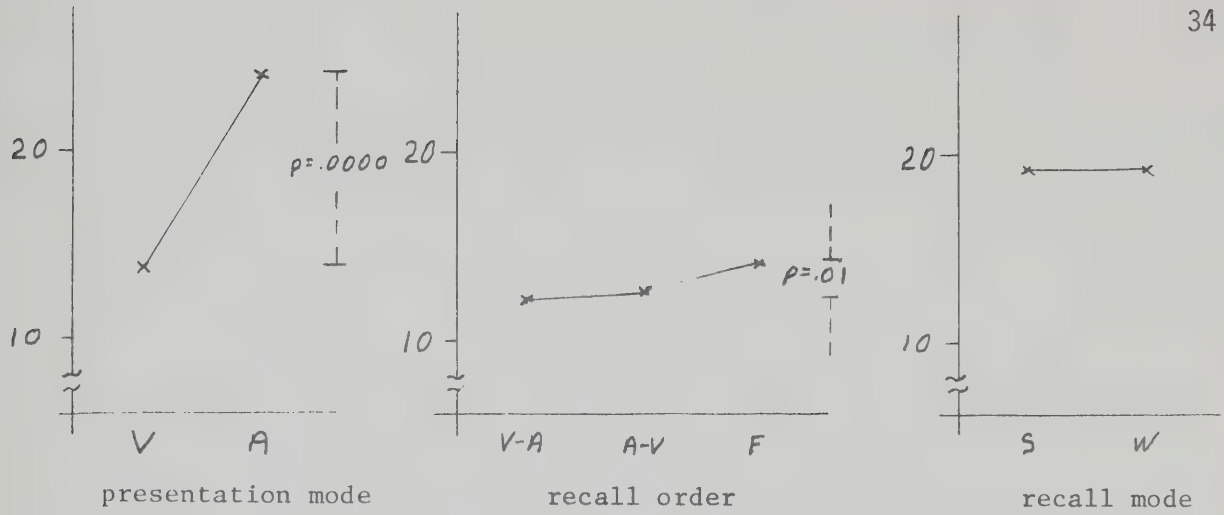

Figure 3: Condition Means at Scoring System I

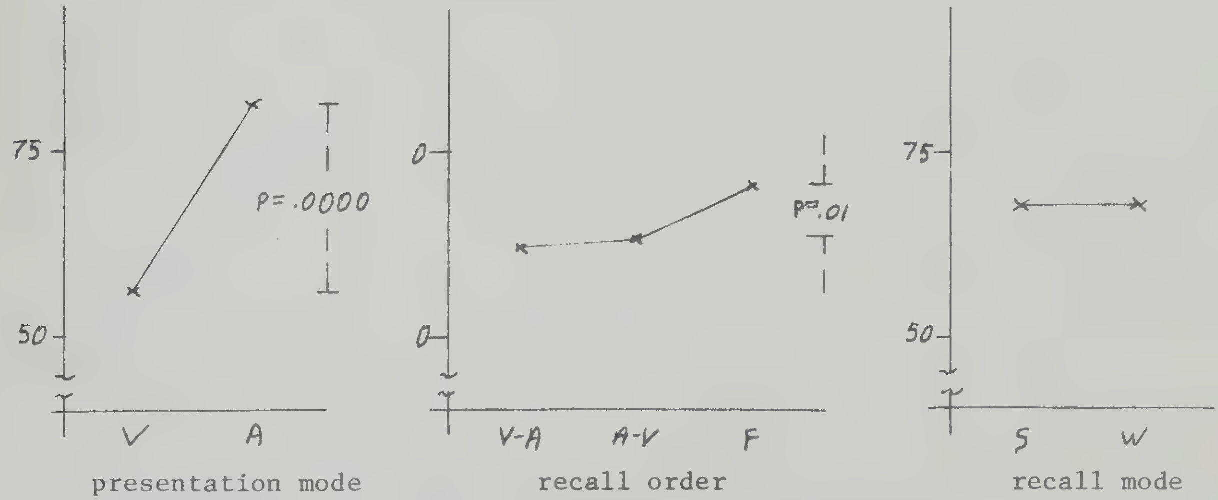

Figure 4: Condition Means at Scoring System II

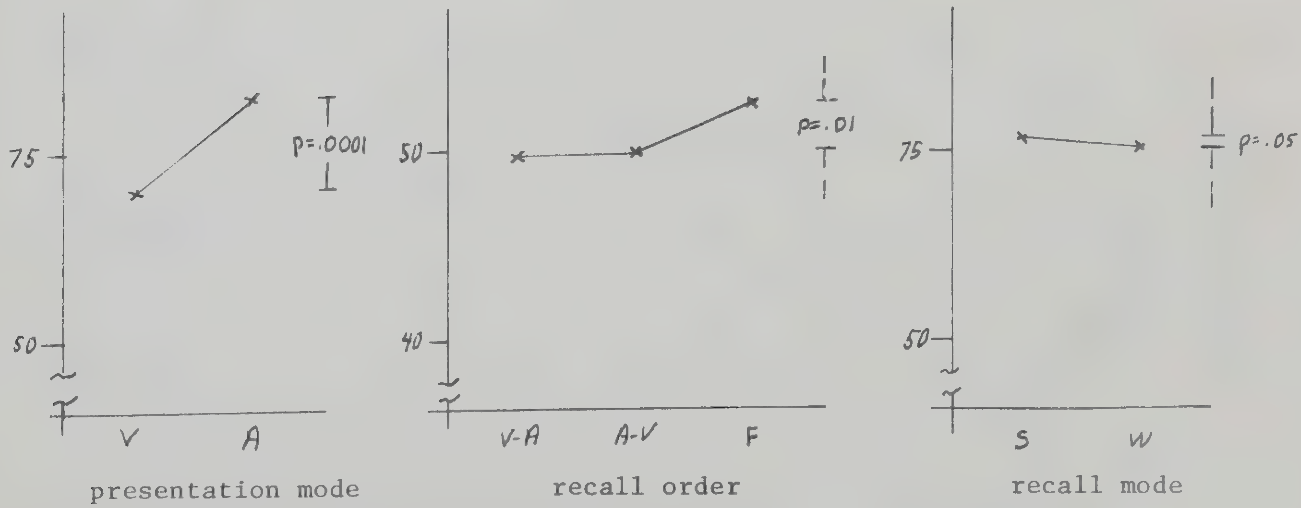

Figure 5: Condition Means at Scoring System III

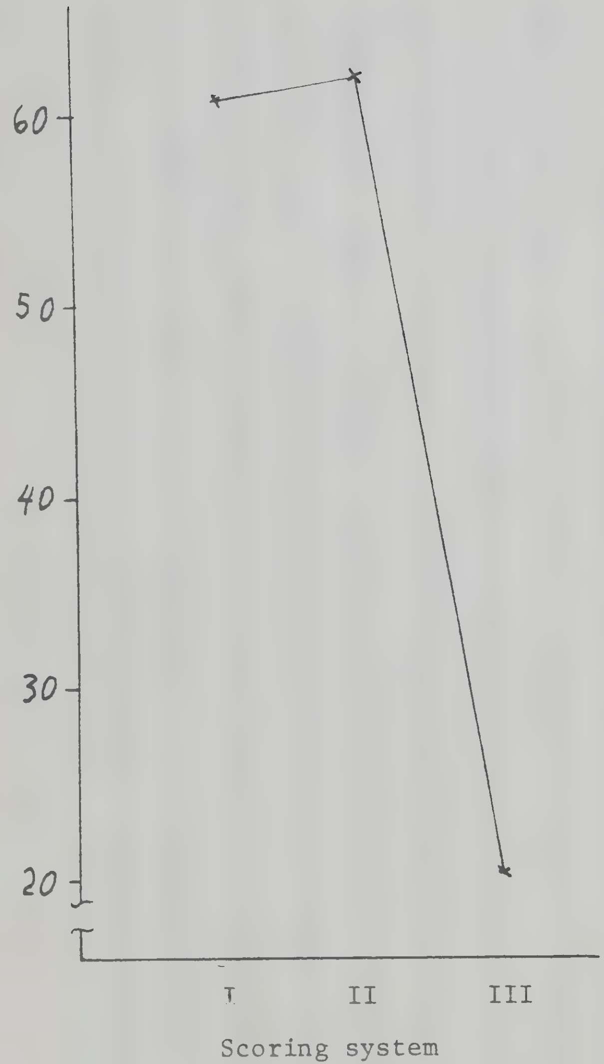

Figure 6:

Presentation Mode

F Ratios

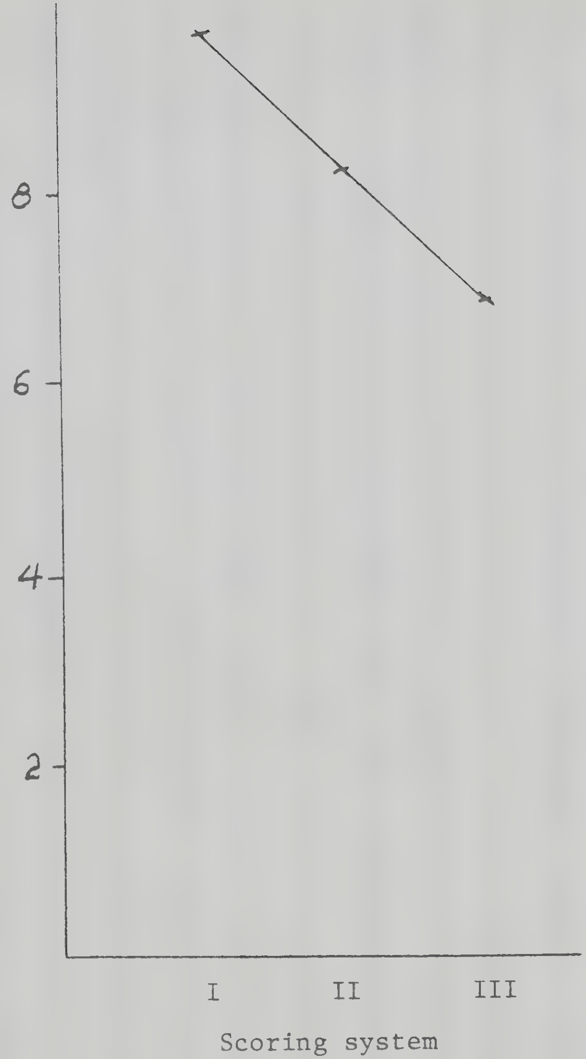

Figure 7:

Recall Order

F Ratios

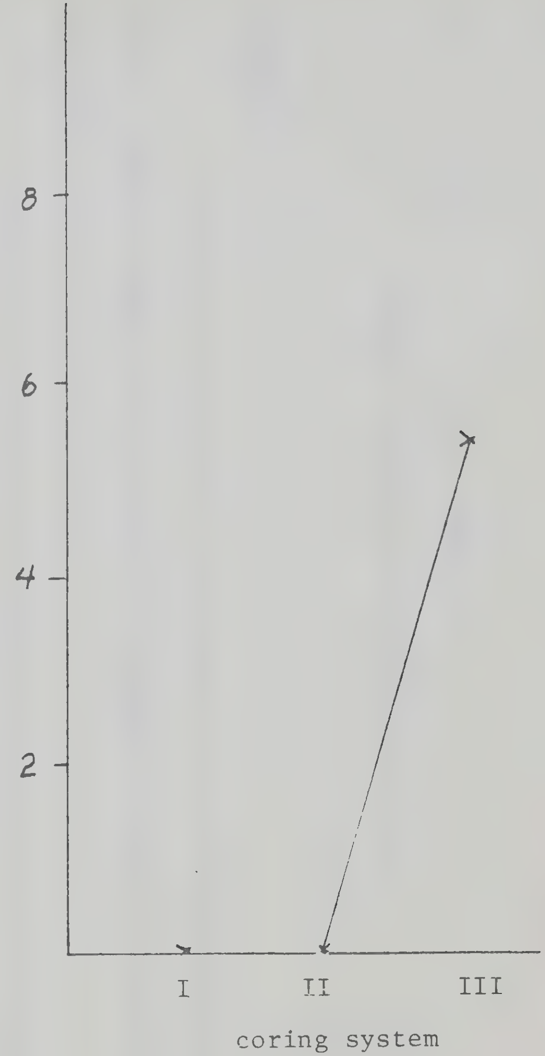

Figure 8:

Recall Mode

F Ratios

CHAPTER V

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

Summary

A bi-sensory experiment was conducted to discern the quality of the stimulus representation which is transferred from the sensory registers to the short-term store.

Atkinson's and Shiffrin's (1968) basic model for the sensory registers and short-term store formed the theoretical nucleus of the study which attempted to elucidate the acoustic confusion phenomenon using bi-sensory stimuli. Atkinson and Shiffrin suggested that the initial component of memory was a sense-dependent store with rapid decay characteristics in which a stimulus is first registered. A representation is then transferred to a short-term store which is common for auditory, verbal and linguistic (a.v.l.) material. Conrad, Wickelgren and others have observed that acoustic confusion arises from the acoustic nature of the representation transferred from the sensory registers to the a.v.l. store.

Prior to performing the present experiment, it was hypothesized that if two stimuli are presented in a competitive manner, the stimulus which is more readily represented and stored will be the one which is more effectively retained. To be more explicit, if the representation between the sensory registers and the a.v.l. store is an acoustic one, and if a visual stimulus and an acoustic stimulus are presented in competition, the acoustic stimulus will undergo fewer re-coding steps and will be more effectively stored. Moreover, if the representations are retrieved, variation in recall accuracy will be in the direction of the

more effectively stored stimulus.

Superior recall of aural stimuli in a competitive aural-visual stimulus situation, then, would give credance to an acoustic representation between the sensory register and the a.v.l. store.

In order to ensure that the stimulus representation between sensory registers and the a.v.l. store, rather than an elaboration of the representation by the a.v.l. store, was the item of study, it was essential to present the stimuli with sufficient rapidity to minimize possible a.v.l. store operations. This involved limiting stimulus duration to only that time required forsensory registration. It also entailed presentation of the stimuli at short enough intervals to prevent elaborating responses. The paucity of information concerning the temporal characteristics of an auditory sensory register necessitated stimulus preparation to be completed with reference to the temporal characteristics of the iconic store. Since Broadbent and Gregory, Margrain, and Noray had already displayed the superiority of aural over visual memory and, in essence, the present study sought the same, it was felt that favouring the visual mode in stimulus preparation would only increase the difficulty of obtaining significant results in the desired direction.

The experiment utilized a photographic technique to simultaneously present bi-sensory pairs of disparate stimuli. The technique facilitated rapid presentation with precise timing controls. Stimulus pairs consisting of single syllable, single digit numbers were simultaneously presented aurally and visually. Three recall orders were employed to overcome the effects of selective attention. Both oral and written recall modes were used to balance for the nature of the decode representation from the a.v.l. store.

Conclusions

Experimental results were generally in the anticipated direction. Storage and recall of aurally presented stimuli were significantly better than storage and recall of visual stimuli under all scoring systems. Moreover, since Scoring System III removed the majority of recall error possibilities, the variation between visual and aural stimulus recall appears to arise in either the registration or encoding stages. If, as Atkinson and Shiffrin (1968) suggested, registration is sensory dependent, there is little reason to expect a differential error rate in the observed direction at this level, especially in view of the advantages granted the visual mode during stimulus preparation. It is not unreasonable to conclude, then, that the observed variation between presentation modes is a result of a differential error-rate operating on the representations transferred between the sensory registers and the a.v.l. store.

The observed variation between recall of visual stimuli and recall of aural stimuli is consistent with our initial hypotheses. The difference could, indeed, be due to an acoustic component in the representation-encoding step. The acoustic confusion phenomena may be considered illustrated.

Unfortunately, several non-empirical observations made during the experiment lead the researcher to believe that the observed variations were not due to acoustic confusion at all, but rather due to a failure to equate aural and visual stimulations. Indeed, the entire concept of bisensory competition is somewhat tenuous, being based on the unsupported assumption that parallel memory systems, with equivalent characteristics, exist for each modality. The differing nature of visual and aural

perceptions--the former being spatial, the latter temporal--alone suggests that attempts to equate, quantitatively, the two modalities, as was attempted in this experiment, is not unlike equating apples with oranges. The validity of bi-senory studies must be seriously questioned.

Subjects commonly commented, following the experiment, that the aural stimuli were more easily recalled because "they kept ringing in your ear". More than one subject remarked that visual-then-aural recall was easiest because "after I wrote down the visual numbers, the aural ones were still there." Tenuous though these and other similar observations are, there is reason to believe that, if an auditory equivalent of the iconic store exists, information decay within such a store occurs much more slowly and the stimulus representation may last several seconds.

Although the existence of an acoustic encode cannot be stated with assurance on the basis of present data, evidence was found to support the existence of a common a.v.l. store. Free recall was consistently superior to directed recall, there being little difference whether the subject was instructed to recall first aural presentations, then visual presentations, or first visual presentations, then aural presentations. Under directed recall, the interpolated operation of determining which numbers to recall first appears to be equally confounding for both directed recall orders. The experimental design does not allow for the determination of interactions between presentation mode and recall order. If the effect of the interpolated activity was similar on both visual and aural stimuli, evidence for a common a.v.l. store would be stronger.

Failure of a variation to appear between recall modes is at once perplexing but consistent with experimental hypotheses. A random alternation between written and spoken recall was introduced into the

experiment to balance for the possibility that short-term stores were sense-dependent and that recall in a mode of the same character as short-term store representation would be favoured. A lack of variation would confirm the effectiveness of the counterbalancing.

Unfortunately, the effectiveness of the counterbalancing poses several logical lemmas. Basic to the study was the assumption that the greater the number of coding operations performed, the lesser the liklihood of performing all operations correctly. Hence the hypothesis was proffered that the stimulus which was subjected to the fewer coding steps would be more effectively recalled. The existence of a common a.v.l. store was also assumed. Complicit with this assumption was the assumption that the nature of a.v.l. representation was common. Empirical evidence existed that the a.v.l. representation had an acoustic character. On the basis of this development, it must be deduced that, if the first assumption was valid, representations subject to the fewer decoding steps would be more accurately recalled. The acoustic component of speech would appear to favour the recall mode. Analyses based on the first two scoring systems fail to confirm this anticipated superiority.

All of which combines to produce a logical problem with several possible solutions. Either a common a.v.l. store does not exist and, hence, decoding operations were applied differentially among stimuli: a common a.v.l. store does exist, but characteristics of the representations stored within it favour neither recall mode; or the first assumption, that increasing the number of operations decreases the probability of correct responses, is erroneous. Should the latter be valid, logical justification for the current study is destroyed. Present data is insufficient to allow resolution of the lemma.

Analysis of recall mode data based on Scoring System III provides a partial solution to the problem. It will be remembered that this system should be the least affected by errors due to recall operations. Observed variations should be due to storage differences. Significant superiority of spoken over written recall, thus, is suggestive of storage variations, a seemingly unlikely outcome since the spoken and written trials were randomly dispersed within the experiment and had common distributions of each of the other experimental dimensions. The third scoring system, while being less sensitive to gross recall errors, is more sensitive to recall errors which affect only a portion of a response. Accordingly, the variation observed between recall modes is in the direction anticipated on the basis of an a.v.l. store with acoustic characteristics.

Other interpretations for the variation between spoken and written recall at the third level of scoring are possible. Many subjects reported that the "public nature" of their spoken responses made them more reluctant to guess on spoken trials than on written trials. Moreover, they claimed to take longer for written responses than for spoken responses. These two factors may have combined to result in a "second-guess" phenomena which detracted from the performance level on written recall.

Interestingly, the various scoring systems had little effect on the overall relationships among levels of the experimental dimensions (see Figures 6, 7, and 8). Only on the recall mode dimension did the scoring systems have an effect. The majority of the errors observed using the first and simplest scoring system, therefore, appear attributable to encoding problems. Moreover, the similarity of the relationships among

levels of the experimental conditions suggests that recall errors are distributed indiscriminantly of at least presentation mode and recall order.

Control processes operating at the a.v.l. store are illustrated by the shift in recall order on free recall trials. Subjects, upon discovering that aural stimuli decayed more slowly than visual stimuli, recalled, with increasing frequency, in the V-A order. Subjects frequently reported increased confidence in their responses following the change in recall strategy.

Pervading most aspects of this study is the superiority of aural short-term memory over visual short-term memory. While consistent with Margrain's (1967) findings which she interpreted as indicative of separate aural and visual memory systems, the present evidence is also consistent with Atkinson's and Shiffrin's (1968) concept of sensory dependent registrations, but a common a.v.l. store. The observed superior recall of aural stimuli may be due to the longevity of representations in the aural sensory register.

Perhaps the most interesting outcome of the current study is quite removed from the results discussed above. That the subjects managed to complete the task at all is amazing. Many researchers, including Broadbent, Gregory, and Margrain, place information processing capacities far below those required to perform on the experimental task. That a subject can receive six distinct stimuli in 5/8 seconds, perform an interpolated operation, and then recall the stimuli with the observed accuracy is, in itself, quite beyond what the literature would lead one to expect.

Implications

Although this study has failed to discover the essence of the representations transferred from the sensory registers to the short-term store, it has immediate implications for both theoretical and applied endeavours. The rapid, sequential presentation of stimuli, within a single modality, may facilitate analysis of coding strategies operating in short-term memory. Sperling (1960), using tachistoscopic presentations, illustrated the control which an individual may exercise over the registration and transfer of simultaneously perceived stimuli. The method of visual stimulus presentation used in this study would be suitable, with minor modification, for investigating similar control processes operating on sequentially presented material. Coding strategies may be trained, also, using a rapid stimulus presentation technique.

The temporal characteristics of auditory memory systems may be further illuminated using aural stimuli similar to those employed in this study. Precise timing--required to determine minimum perception times, decay characteristics, and confusability of simultaneous stimuli--may be achieved using the manual audio tape splicing techniques developed for this study.

Bi-sensory presentations may provide interesting results if applied to paired associate learning tasks.

Within the classroom environment, the present study supports the continued use of phonetic reading instruction. The superiority of aur, over visual, short-term memory suggests that oral instructions will be more effective than written instructions. This possibility should be considered in both machine and television teaching situations. The use of audio-visual materials--with strong audio components--is also supported.

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APPENDIX A

APPENDIX A

STIMULUS FILM

Justification

Preparation of a complex, precise stimulus presentation system constituted, in the author's view, the greatest challenge of this experimental study. The limited number of aural-visual bi-sensory studies conducted previously commonly employed imprecise methods with only gross controls for stimulus onset. stimulus duration, inter-stimulus interval, and stimulus intensity. Various techniques have been attempted. Madsen, Rollins, and Senf (1970) used stimuli printed on Bell and Howell Language Master cards with attached magnetic audio strips. As the magnetic strip passed by the recorder's playback head, the visual stimulus was presented through a wooden shield. They admit to only rough timing controls and made no attempts to equate inter-modal stimulus intensities. Moreover, the visual stimulus was presented while moving across the viewing field rather than being stationary as might be preferred.

Margrain (1967) was still less sophisticated. She employed standard 1/4 inch magnetic audio-tape with visual stimuli stencilled on the tape's glossy side. Timing--accomplished with a stop-watch--was gross and her method for ensuring simultanaeity of bi-modal stimuli--stopping and starting the tape transport--left much to be desired. She also employed a moving visual stimulus and with visual stimuli being less than 1/4 inch high, apparently made no attempt to equate the magnitudes of the visual and aural cues.

Broadbent and Gregory (1961) used a method similar to Margrain's.

Another study by the team (1965) employed a more imaginative technique--network television. Their description of this presentation technique is too abbreviated to evaluate the method's precision.

Before initiating stimulus film preparation, several other methods--including audio-video tape, a multi track audio tape with inaudible signals for activating nixie tubes, and the Division of Education Research Services', University of Alberta, IBM 1500 computer with CRT and audio output were investigated. The sheer complexity of the systems and their dependence on mechanical-electronic timing circuits constituted rejection grounds for the A-V tape and audio tape-nixie tube set-ups. Stimulus duration could not be sufficiently controlled using the computer method.

Ultimately, a sound-movie film was recognized as the most practical system. Although tedious to prepare, film has several distinct advantages over other methods. Stimulus timing--onset, duration, inter-stimulus interval--can be precisely controlled through mechanical editting. Once prepared, the film's characteristics are fixed and do not fluctuate across subjects. Presentation equipment has a low-level of complexity and is therefore relatively free from malfunction difficulties. Although the stimuli are fixed with respect to order and timing, their physical magnitudes may be readily manipulated in attempts to equate intensities. The film may be presented in a darkened room, thus masking visual environmental interference.

Countering advantages of film presentations are two major drawbacks: high cost and high technical demands. The first limitation was minimized by many improvisations in film materials and professional lab work. Unfortunately, the improvisations generally tended to decrease the quality of

the finished film. The second difficulty, the high level of technical competence required, was neutralized by the experimenter's photographic knowledge. If all technical work had been contracted out, the cost of the film would have been prohibitive.

Description

The stimulus film consisted of a 16 mm sound movie with 60 trials each containing three aural-visual pairs. An aural-visual pair was comprised of a visual digit of .125 seconds of blank film, and each trial by a 1 second coloured strip and a 9 second segment of dark-purple film base. Preceeding each trial by 2 seconds, the film base changed from deep-purple to black, constituting a visual attention cue. The film's sound track was blank except for the aural stimuli.

Preparation

Initially, 5/8 inch Letraset digits were transferred individually onto 1 1/2 inch by 1 1/4 inch acetate sheets. The acetate sheets were then mounted in standard 35 mm cardboard slide mounts. A master stimulus pack consisting of the digits 1, 2, 3, 4, 5, 6, and 9 was thus prepared.

The digits were then copied, in the appropriate random order, on 16 mm Plus-X reversal film. For each visual stimulus presentation, a slide was copied for three frames. Three blank frames were then recorded before copying three frames of the next visual stimulus. A short length of film, sufficient to allow sound leading, was left between each trial of three visual elements. In this manner, all 60 trials were photographed on a single 100 foot roll of film.

The aural digits were recorded on 16 mm sprocketed magnetic audio tape using a Magnasynch sound recorder and the experimenter's voice. To

ensure uniformity of amplitude and pronunciation across digits and to maintain the required crispness and short duration, each digit was pronounced carefully and rapidly, several of the same digit in quick succession. Eight sets of the required spoken digits were thus recorded.

Using a Steenbeck 16 mm movie film editing table, the aural digits were isolated on the magnetic tape, trimmed to the required three-frame length, and manually spliced into a blank roll of magnetic tape. Although the digits 2, 3, and 8 were easily edited to the required .125 second duration by merely dropping a short portion of the final phoneme, the other digits were not so easily cut. Short portions (approximately .02 seconds) of the initial phoneme of the digits 1, 4, 5, and 9 had to be trimmed along with a similar portion of their concluding phoneme. Unfortunately, the editing of these digits occasionally interferred with their phonemic character. In some instances, dropping portions of the first and last sounds of f ī v and n ī n left only a dominant ī sound which was readily confused during presentation (Figure 9). A similar confusability emerged between 1's and 4's. As each trial was prepared from new sound elements, the confusions were not prominent in all instances and, indeed, were limited to approximately 6 of the 60 trials.

The digit 6 proved the most challenging to record. Intricate editing and splicing was required to compress its lingering sounds into the allowed time interval. Indeed, the shortest pronunciation of 6 which the experimenter could maintain was a full .3 seconds. This constituted a 7-frame segment which had to be trimmed to but 3 frames. Surprisingly, by selecting 1-frame portions of the sound, a 3-frame conglomerate was synthesized which preserved the phonemic character of the sound (Figure 10).

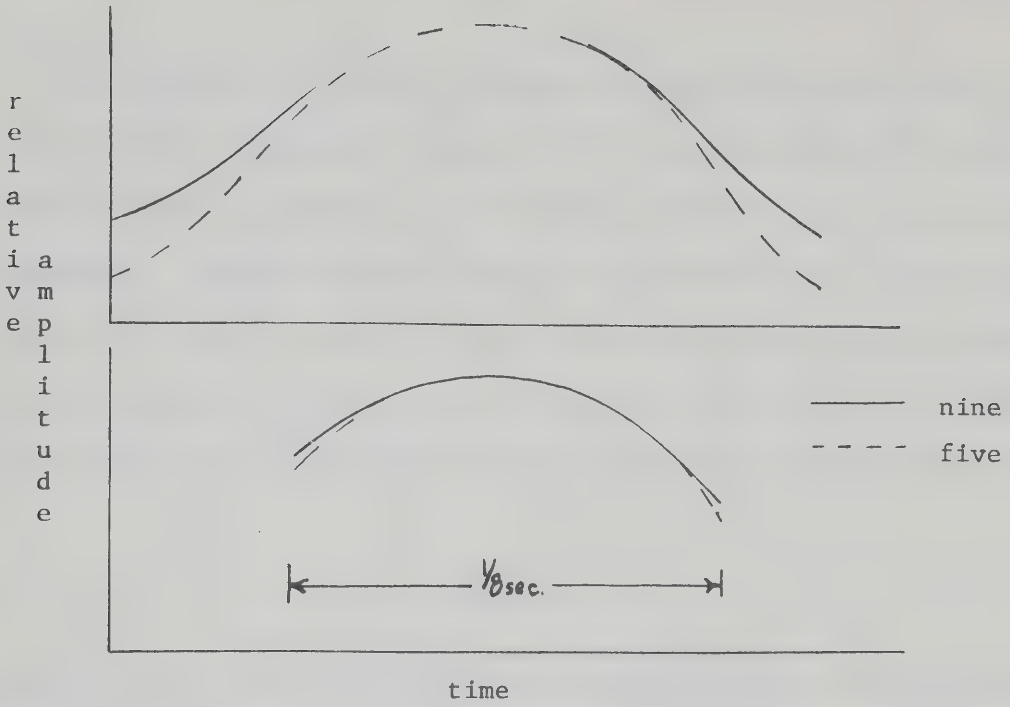

Figure 9. Editing of Aural Digits 5 and 9

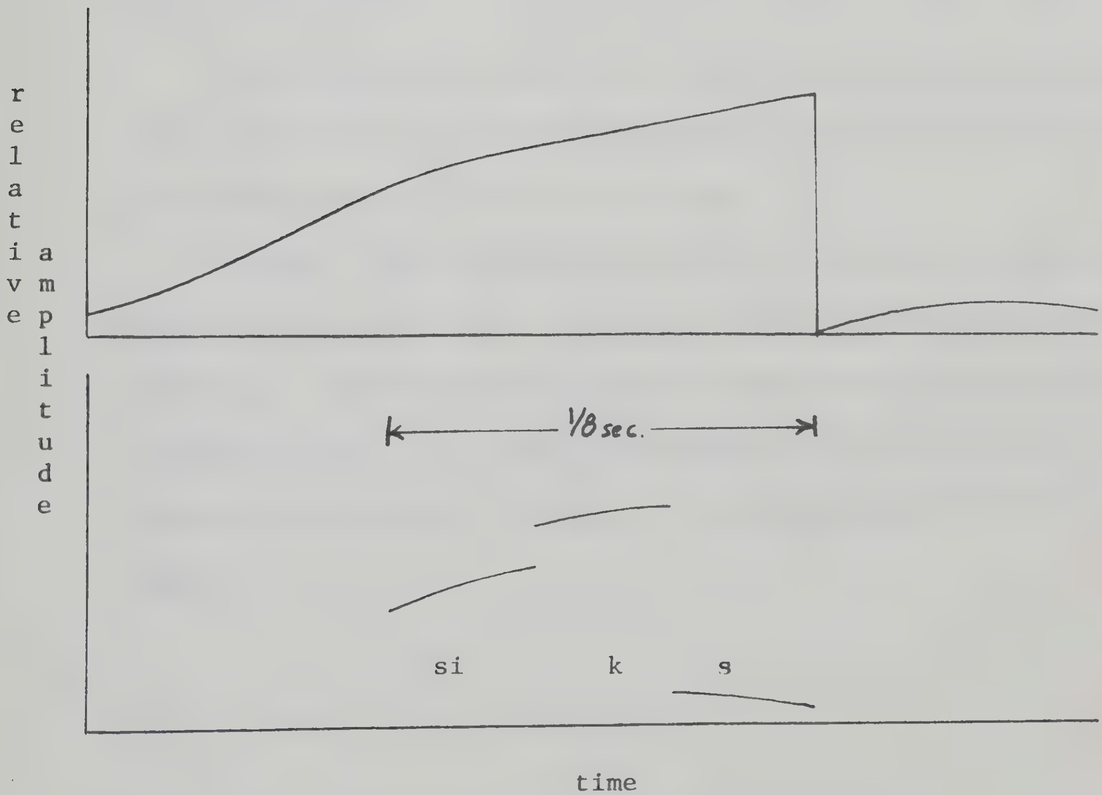

Figure 10. Editing of Aural Digit 6

As each aural digit was prepared, it was synchronized with its appropriate visual component. A set of 20 trials (less than 20 seconds presentation time) was prepared in this manner, at the expense of nearly 24 man-hours. Recognizing the unfeasibility of similarly producing the remaining 40 trials, it was decided to cross dub the master audio tape three times, on each occasion beginning at a different trial (Table 16 . Hence, although each visual trial was unique, aural trials were repeated three times.

TABLE 16

Pairing of Aural and Visual Stimuli

Visual Trial Number	1.......20, 21....30, 31...39, 40......56, 57..60
Aural Trial Number	1.......20, 10....20, 1....9, 5......20, 1...4

A synchronization check was conducted on each element of the 60 final trials before the film and sound track were forwarded to a commercial lab for copying and optical sound printing.

Coloured, 24-frame strips of waste film base were next manually spliced after each trial, followed by 216 frames of waste, dark-purple film base. The head of the next trial was then spliced and the process repeated (Figure 11). Using this method, the 400 foot-plus film was constructed using only 100 feet of costly, professional lab-prepared material.

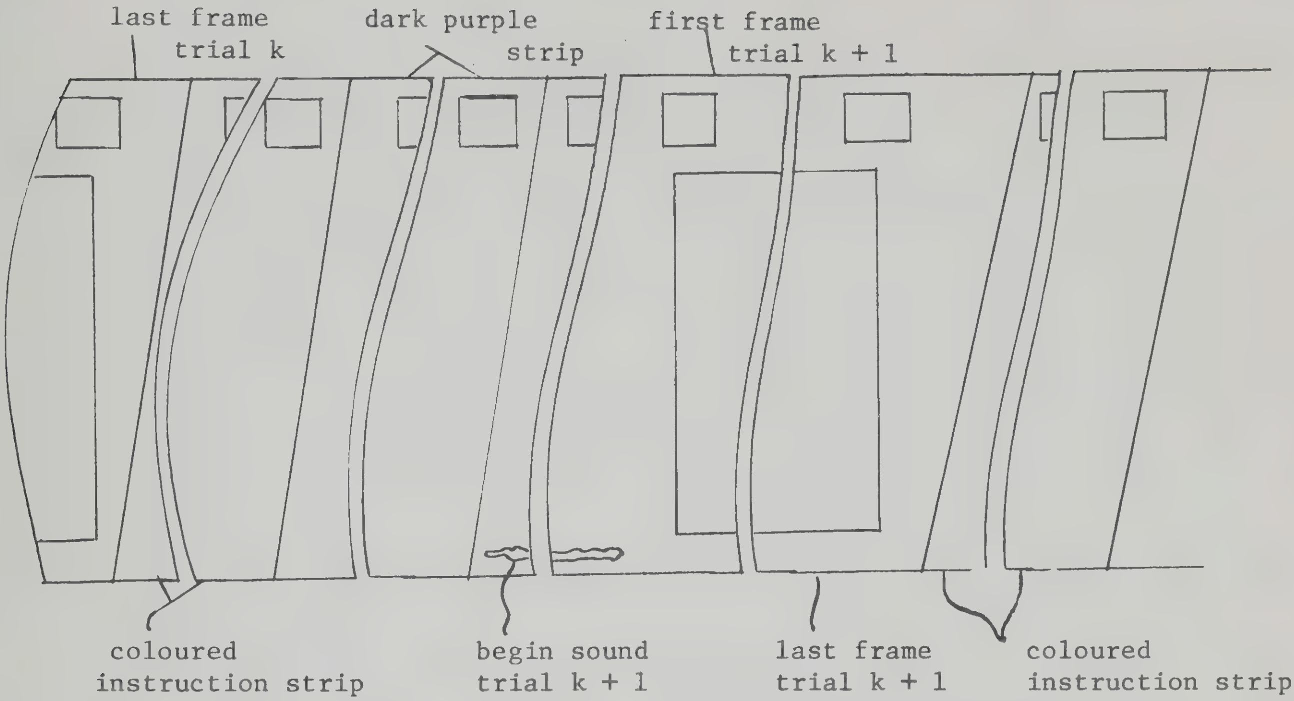

Figure 11. Format of Stimulus Film

APPENDIX B

APPENDIX B

BISI INSTRUCTION SET

In a few moments you will be shown a movie which consists of sequences of numbers. As you see numbers on the screen, you will also hear numbers through the earphones. The numbers which you see may not always be the same as the numbers which you hear. After each sequence of numbers has ended, your task will be to recall all the numbers which have been presented.

The end of each sequence will be marked by the projection of a colour on the screen. The colour will indicate the order in which you are to recall the numbers. When the colour red is projected, your task will be to report first the numbers you saw, then the numbers you heard. When the colour green appears, you are to report first the numbers you heard, then the numbers you saw. When the colour yellow is projected, you may report the numbers in any order you wish. To go over that again, red means report first the numbers seen, then the numbers heard; for green, report first the numbers heard, then the numbers seen; for yellow, report the numbers in any order you wish.

As the colours are projected, you will hear a message over the earphones indicating how you are to make your report. If you hear the word "write", write the numbers on the paper in front of you. If you hear the word "speak", say the words aloud and I will record them. Remember, you are always to report the numbers in the order indicated by the projected colour. For red, report first the numbers seen, then the numbers heard; for green, report first the numbers heard, then the numbers seen; for yellow report the numbers in any order you wish.

The film will last approximately 12 minutes. During that time you will see and hear many different sequences. If you have trouble recalling a sequence, don't worry about it; you will have many other opportunities. Simply try to pay as close attention as possible to each set of numbers.

Do you have any questions?

Very well, let's begin. Remember, for red, recall first the numbers seen, then the numbers heard; for green, recall first the numbers heard, then the numbers seen; for yellow, recall the numbers in any order you wish.

APPENDIX C

APPENDIX C

BISI SCORING SHEET

SUBJECT NUMBER ______ DATE: APRIL ___, 1971

Trial	Col.	W/S	Correct R	Response	Order	Vis.	Aur.	
1	red	s	225 513					
2	gre	s	113 525					
3	yel	w	892 483					
4	gre	w	525 241					
5	red	w	283 298					
6	red	w	526 142					
7	yel	s	689 651					
8	gre	w	293 651					
9	gre	s	156 483					
10	yel	w	252 832					
11	red	w	381 499					
12	yel	s	165 941					
13	red	w	462 154					
14	gre	s	968 432					
15	gre	s	321 322					
16	red	s	382 683					
17	yel	w	145 935					
18	gre	w	652 614					
19	red	s	341 932					
20	gre	s	654 219					
21	red	w	833 499					
22	gre	s	941 281					
23	yel	s	192 154					

Trial	Col.	W/S	Correct R	Response	Order	Vis.	Aur.	
24	yel	w	641 968					
25	yel	s	332 321					
26	red	s	366 683					
27	gre	s	935 339					
28	gre	w	652 344					
29	red	w	652 932					
30	yel	w	962 654					
31	yel	s	816 513					
32	red	s	565 113					
33	gre	w	483 588					
34	yel	w	553 525					
35	red	w	236 298					
36	yel	w	885 142					
37	yel	s	346 651					
38	yel	w	222 293					
39	gre	s	156 136					
40	red	w	953 832					
41	gre	s	525 151					
42	red	s	653 298					
43	red	w	899 142					
44	gre	w	651 464					
45	yel	s	815 293					
46	gre	s	156 869					
47	gre	w	832 529					

Trial	Col.	W/S	Correct R	Response	Order	Vis.	Aur.	
48	red	w	616 499					
49	yel	s	988 941					
50	red	s	264 154					
51	yel	w	968 968					
52	gre	s	321 146					
53	gre	s	683 288					
54	yel	w	366 935					
55	red	s	929 052					
56	red	s	549 932					
57	yel	s	533 654					
58	gre	w	513 451					
59	gre	w	113 886					
60	red	w	361 483					

APPENDIX D

APPENDIX D

DEBRIEFING AND QUESTIONNAIRE

The experiment in which you have just participated is an attempt to study memory processes using rapidly presented audio and visual signals. As you have noticed, the aural and visual numbers were precisely synchronized and lasted for only very brief intervals.

Numbers presented in this manner are very difficult to remember. Indeed, some memory researchers speculate that the recall task which you performed is not possible. You were expected to make many errors when giving your reports.

Error patterns in your reports comprise the main source of experimental data. Our primary hypothesis is that numbers presented by one mode will be reported with consistently greater accuracy than numbers presented by the other mode. The results have implications for several areas of education including reading instruction, linguistics, and audio-visual applications.

Before you leave, there are several questions we would like you to answer. Use the remainder of this page for you responses.

1. Which numbers did you find easier to remember, the aural or the visual?

2. On which set of numbers--the aural or the visual--did you generally focus your attention during the experiment?

3. Did you ever rehearse--that is, practice--any of the numbers? Which ones? How often? When did you rehearse them?

4. Did recalling one set of numbers make the other set harder to remember? Explain.

5. Your own reactions.